Operational Process for a Data Bus for a Plurality of Nodes

The invention relates to an operational process for a data bus for a plurality of nodes as follows from the German Patent Application 19720401.5 not previously published. Each telegram possesses an unambiguous identifier which determines the urgency of the telegram.

The data bus possess for at least one part of the nodes optical transmission segments up to the star coupler. If it is an electric star coupler these telegrams are converted into an electric signal telegram and converted via a receiver/transmitter unit once again into a preferably optical signal telegram which is thus transmitted to all the remaining nodes. A data bus of this type with at least one partially optical transmission segment possesses to that extent a particular characteristic as the signal transit time, that is, the time for the transmission of a signal (telegram) from one node to another is significantly greater than the bit time. In contradistinction thereto the signal transit time in the case of a purely electrical data bus, as, for example, is frequently used in vehicles under the designation CAN, is significantly smaller than the bit time. An additional difficulty due to the sharply differing of the signal transit times arises when additional nodes are connected to the data bus which themselves output (only) electrical signal telegrams.

Cancel

An example may illustrate this. Let us assume, as represented in Figure 1, a star-shaped bus system with altogether four nodes T1 to T4 in which nodes T1, T2, and T3 are connected via an optical transmission segment L1, L2, and L3 to an active electric star coupler K. Between each of the nodes T1 and T3 and the star coupler K two SE (transmitter/receiver) units SE_{11}, SE_{12}, SE_{21}, SE_{22}, SE_{31}, and SE_{32} are disposed in which the electrical telegram present originally at the nodes is converted into an optical signal and is reconverted into an electrical signal telegram which then is given to the star coupler K. In reverse, the optical telegrams intended for the nodes starting originally from the star coupler are converted into optical telegrams and then, in turn, into electrical receiver signals.

Furthermore, an additional node T4 is disposed which is a node which is connected via an electrical transmission segment directly to the star coupler K.

Depending on the conversion time for the electrical into optical signals and vice versa (about on the order of magnitude of 60 - 100 ns each) and the transit time in the optical transmission segments (ca. 5 ns/m), transit times for telegrams of each of the nodes T1 to T3 to and from the star coupler K follow which are specified in the exemplary embodiment by way of example as 180, 240, and 200 ns. The transit time of the signals from node T4 to the star coupler K is ideally equal to 0 ns.

If one assumes, for example, a telegram which is supposed to go from node T1 to node T2 via the star coupler K, then a transit time of at least 420 ns results, for a telegram from node T3 to T2 of even 440 ns. The minimal signal transit time for telegrams here between the nodes T1 and T4 is 180 ns.

It can be seen without further effort that the transit time in the system depends strongly on the respective individual delay times in the transmission segments of the individual nodes to the active star coupler and moreover is significantly greater than the bit time, here, for example, assumed equal to 100 ns.

Let us now assume signal traffic on the data bus as follows from Figure 2 and the older patent application mentioned earlier. Between two synchronization pulses which are output by a bus master, a data transaction takes place on the data bus. In each of the cycles designated as cycle 1, cycle 2, and cycle 3 at most three telegrams are output which are the telegrams t1, t2, and t3 or t1, t4 and t5 or the telegram t3 alone. Between each of the telegrams actually transmitted at least one wait time must be adhered which follows from the following equation.

Wait time: [see original German patent, Page 3, Line 8 for equation]

Therein t_wx0 means a fixed percentage which serves to unambiguously distinguish telegram and wait time, t_wx_delta a fixed multiplication percentage which depends on the maximal signal transit time in the bus system, and ID - ID_{x-1} the difference of the telegram identifier. Therein ID stands for the identifier of the telegram actually to be sent by the node and ID_{x-1} for the identifier of the last telegram actually transmitted.

As can be seen without further effort the distance is minimal between two transmitted, and with regard to their identifier, sequential telegrams, therefore between the telegrams t1 and t2 or t2 and t3 as well as between t4 and t5. However, for telegrams not directly sequential with regard to their identifier, such as t4 after t1 in cycle 2, it is greater.

With the aid of Figure 3 the calculation of the multiplication percentage t_wx_delta following from the transit times is to be explained.

Let two nodes be assumed, designated here as A and B. Node B transmits a telegram with ID = 1 and node A a telegram with ID = 2. Furthermore, let node A be assumed as bus master. It transmits the synchronization pulse and starts, after the end of the synchronization pulse, the wait time t_wx. The node B sees the end of the synchronization pulse but delayed by t_max and thus starts its wait time t_wx t_max later. Node B begins after the expiration of the wait time

[see original German patent, Page 4, Line 3 for equation]

with the transmission of the telegram ID = 1. This telegram in turn needs t_max in order to arrive at node A. Node A must still be able to receive this telegram before it, for its part, begins with the transmission of the telegram ID = 2. The following equations must therefore be satisfied from the standpoint of node A in order to avoid a collision.

Start time telegram ID = 2 > Receiving time telegram ID =1

[see original German patent, Page 4, Line 12 for equation]

For this it follows

[see original German patent, Page 4, Line 15 for equation]

In the case of the exemplary configuration t_wx_delta=880ns thus follows from Figure 1. In case of large identifier differences, for examples $(ID - ID_{x-1}) = 250$ a wait time of over 220 μs thus results. This means that in the case of a required cycle time of, for example, 200 μs telegrams with high identifiers cannot be transmitted at all. Furthermore, the net data throughput also sinks with the use of small IDs with t_wx_delta becoming greater.

The objective of the invention is to provide an operational process for a data bus for a plurality of nodes in which the degree of efficiency is increased by the wait time between the telegrams to be transmitted being reduced.

The invention realizes this objective with the characteristics of claim 1.

This solution consists in brief of adjusting the transit times delays, in particular between the nodes and the active star coupler. In the ideal case this adjustment should be performed to the extent that the signal transit times between the nodes and the star coupler are equal. The measures according to the invention consist of adapting the fixed percentage of the wait time t_wx0 individually.

The invention will be concretized by various measures. These measures are the object of claims 2 and 3. They can be applied jointly or alternatively. These measures are explained with the aid of the additional figures.

Shown are:

Figure 4 a diagram for the explanation of the measure specified in claim 2

and

Figure 5 a diagram for the explanation of the measure specified in claim 3.

As specified in claim 2 and represented in Figure 4, the nodes distinguish the transmitting and receiving case for the last bus activity. The node which has transmitted the last bus activity (sync pulse or telegram) waits by t_min longer than the (= all other) nodes which have received this bus activity. In place of the universal fixed percentage t_wx0 a fixed percentage t_wx0_tx for the transmitting case or t_wx0_rx for the receiving case now appears.

[see original German patent, Page 5, Line 22 for equation] is for the transmitting case.

[see original German patent, Page 5, Line 23 for equation] is for the receiving case.

The following wait time must be satisfied from the view of node A in order to avoid a collision.

Start time telegram ID = 2 > Receiving time telegram ID =1

[see original German patent, Page 5, Line 30 for equation]

For this it follows

[see original German patent, Page 5, Line 32 for equation]

Thereby the value of t_wx_delta can be reduced from 880 ns to 700 ns in the exemplary configuration of Figure 1.

In addition or alternatively, as specified in claim 3, the fixed percentage of the wait times t_wx0_tx and t_wx0_rx for each node is adapted to its individual delay time (here called delay_tln). This happens according to the following formulas.

[see original German patent, Page 6, Lines 8 and 9 for equations]

The parameters used herein have the following meaning.

Table 1

[Column 1]

Parameter:

[see original German patent, Page 6, Line 12 for entries]

[Column 2]

Meaning:

Maximal delay of a signal from the electrical part of the star coupler to the node tln in the worst case

Maximum (delay_tln_1, delay_tln_2, . . .)

Minimal "Bus Idle" time between telegrams

Multiplicative factor of the wait time

[Column 3]

Example:

delay_μP, delay_μC1, delay_μ2

Here: delay_tln_max = 240 ns

1100 ns

In the ideal case: t_max

If these equations are applied to the bus configuration of Figure 1, then the parameters follow as entered in Figure 5 for the individual nodes. In Figure 5 the signal curves are furthermore shown which the individual nodes see at their bus connection.

It can be seen from Figure 5 that by the adaptation of the fixed percentage of the wait time t_wx0_tx and t_wx0_rx the nodes are synchronized. The start time of a telegram then no longer depends on the different signal transit times in the system (from optical and in a given case electrical transmission segments from and to the star coupler) but rather

only on the identifier of the telegram to be transmitted and the, in a given case, allocation of the data bus by a (more important) telegram with lower identifier. If the nodes would all transmit one and the same telegram with an identical identifier, they would do this simultaneously. Since only one node transmits each telegram with a certain identifier, a collision of telegrams is ruled out.

Thus the following now applies.

[see original German patent, Page 7, Line 7 for formula]

Thereby a halving of the multiplicative percentage of the wait time t_wx_delta is achieved. In the exemplary configuration of Figure 1 this means for t_wx_delta a value of 440 ns with respect to 880 ns. High identifiers, for example, ID = 250 have a wait time of ca. t_wx = 110 μs and therefore can still be transmitted within a cycle of 200 μs.

Since in the normal bus operation many different and, thus, also higher identifiers are used, only rarely are directly sequential identifiers transmitted within one frame. Thus the halving of t_wx_delta causes approximately a halving of the wait times t_wx. This has, in turn, nearly a doubling of the net rate of data throughput as a consequence. Overall, therefore, the degree of efficiency of the protocol is increased. In the case of a fixed net data rate the gross rate of data throughput can thus be lowered. Thereby cost

reductions are possible due to the lower frequency of signals, for example, the EMC protection can be structured more simply and not such high demands must be made of the structural parts.

For the realization of the invention adaptation and logic elements not represented are provided in the nodes which perform the specified adjustments of the starting time points for the telegram as a function of the immediately preceding activity (transmitting or receiving) of the node itself and the individual signal transit time between the node and the star coupler. Since as shown significant transit time differences between nodes with electrical connection and the nodes with optical connection are present, it is sufficient to approximately compensate these transit time differences by delaying the transmission of only the node with electrical connection by a time span which is approximately equal to the average delay time of the node of the other type (with optical connection). A sufficiently close value follows, for example 210 ns.